Constraining interpretations of quantum mechanics

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SUPERLUMINOUS EVENT MAY LOSE Supernova Status

In June 2015 the All-Sky Automated Survey for Supernovae snagged a huge fish: an extremely luminous object, dubbed ASASSN-15lh, whose spectrum appeared consistent with that of a supernova. The object’s luminosity peaked at about $2.2 \times 10^{45} \text{ erg/s}$ ($2.2 \times 10^{38} \text{ J/s}$), a factor of two higher than that of any other measured stellar explosion (see PHYSICS TODAY, March 2016, page 14). Yet the ramifications of the supernova interpretation, including the sheer scale of nucleosynthesis necessary to generate so much energy, led scientists to consider alternative mechanisms.

Following a 10-month examination at multiple wavebands, one research team now argues that ASASSN-15lh is actually a star that got torn apart by the extreme tidal forces of its galaxy’s supermassive black hole (SMBH). The scientists, led by Giorgos Leloudas from the Weizmann Institute of Science in Israel and the University of Copenhagen in Denmark, found that ASASSN-15lh went through three distinct spectroscopic phases, including one with helium emission lines that have never been detected in the brightest supernovae. Further support for the researchers’ proposal comes from the location of ASASSN-15lh.

The event took place at the center of a massive red galaxy whose star formation rate has all but petered out. Such galaxies harbor SMBHs but not the young blue stars whose lives end in supernovae. The researchers also observed a second peak in UV emissions about two months after ASASSN-15lh, which is consistent with the behavior of a previous transient that is thought to be a tidal disruption event.

In making their case, Leloudas and colleagues faced one major objection: The SMBH in question is so massive that it should swallow stars whole rather than shredding them first. The researchers circumvented that problem by proposing that the black hole is rapidly spinning (see artist’s conception here), which can extend the range of strong tidal forces by nearly an order of magnitude. (G. Leloudas et al., Nat. Astron. 1, 2, 2016.) —AG

CONSTRaining INTERPRETATIONS OF QUANTum MECHANiCS

John Stewart Bell’s famous theorem is a statement about the nature of any theory whose predictions are compatible with those of quantum mechanics: If the theory is governed by hidden variables, unknown parameters that determine the results of measurements, it must also admit action at a distance. Now an international collaboration led by Ádám Cabello has invoked a fundamental thermodynamics result, the Landauer erasure principle, to show that systems in hidden-variable theories must have an infinite memory to be compatible with quantum mechanics.

In quantum mechanics, measurements made at an experimenter’s whim cause a system to change its state; for a two-state electron system, for example, that change can be from spin up in the z-direction to spin down in the x-direction. Because of those changes, a system with hidden variables has to have a memory so that it knows how to respond to a series of measurements; if that memory is finite, it can serve only for a limited time. As an experimenter keeps making observations, the system must eventually update its memory, and according to the Landauer principle, the erasure of information associated with that update generates heat. (See the article by Eric Lutz and Sergio

References
THE SPACE WEATHER ON THE CLOSEST EARTH-LIKE EXOPLANET

In August 2016 hints were confirmed that an Earth-like planet orbits the Sun’s nearest stellar neighbor, the red dwarf Proxima Centauri. The discovery excited astronomers. Proxima Centauri is close enough that the exoplanet, Proxima Centauri b, will be directly visible to the next generation of space telescopes and to the giant ground-based telescopes currently under construction. (The accompanying artist’s impression depicts Proxima Centauri as seen from the exoplanet surface.) Furthermore, the exoplanet’s orbit lies within the star’s habitable zone—that is, the volume of space within which a planetary surface can sustain liquid water given enough atmospheric pressure. Does the exoplanet have a thick atmosphere? To begin to address that question, Cecilia Garraffo of the Harvard–Smithsonian Center for Astrophysics and her colleagues modeled the hot wind of charged particles that emanates from Proxima Centauri. Because the precise values of the star’s magnetic field and the exoplanet’s orbital inclination and eccentricity are unknown, the researchers ran their magnetohydrodynamic model eight times with different sets of parameters. According to the model, Proxima Centauri’s wind is roughly as strong as the Sun’s, even though the red dwarf is smaller and dimmer. But because of Proxima Centauri’s low luminosity, its habitable zone lies much closer to the star than the Sun’s does. For all eight scenarios, the wind that buffets Proxima Centauri b is approximately 1000 times more powerful than solar wind is at Earth’s orbit. Even though the exoplanet likely has a magnetic field, whatever atmosphere the exoplanet was endowed with was likely blown away long ago. (C. Garraffo, J. J. Drake, O. Cohen, *Astrophys. J. Lett.* **833**, L4, 2016.) —CD

PITCH SHARPENING IN WOODWINDS

Today’s concert woodwinds feature as many as two dozen tone holes and a bevy of levers, called keys, that put the full chromatic scale over multiple octaves at a player’s fingertips. Yet even on keyless instruments, like the recorder, bagpipe chanter, and the Japanese shakuhachi, a player can use so-called cross-fingering to fill in the chromatic gaps: Covering one or more tone holes below the first open hole usually lowers, or flattens, the pitch by a semitone. But in what’s known as an intonation anomaly or pitch sharpening, cross-fingering can, in some circumstances, raise the pitch.

The flute is often presented as an example for understanding wave resonances: The open hole closest to the player’s mouth sets the effective length, which in turn determines the resonant frequencies and thus the notes produced. Although the actual pitch details aren’t quite that simple, the behavior is for the most part well understood and amenable to numerical calculation. Yet pitch sharpening has gotten little attention. Now Seiji Adachi at the Fraunhofer Institute for Building Physics in Stuttgart, Germany, offers an explanation of the effect by modeling a minimal system—a flute with one open tone hole—as a system of coupled oscillators. Closed tone holes below the open hole essentially create a downstream pipe of adjustable length. The upper and lower flute sections will have their own resonant frequencies, but since the sections interact, the resonances shift—some higher, some lower. Moreover, some of the coupled modes are more easily excited than others. By extending his model to include an additional resonant mode in the upper bore, Adachi could quantitatively account for both pitch flattening and pitch sharpening in an actual recorder. (S. Adachi, *Acoust. Sci. Tech.* **38**, 14, 2017.) —RJF

Heat need not be produced in a hidden-variables theory if a system could store unlimited information. Such is the case, for example, for David Bohm’s version of quantum mechanics, in which a continuous pilot wave serves as the information repository. And in formulations of quantum mechanics without hidden variables, such as in the Copenhagen interpretation, heat is not generated because there is no deterministic register to update. (A. Cabello et al., *Phys. Rev. A* **94**, 052127, 2016.) —SKB